Stellar Parallax Papers, No. 3.

The Parallax of Eight Stars, from Photographs taken at the Cambridge Observatory by Arthur R. Hinks, M.A., and the writer. By Henry Norris Russell, Ph.D.

The following results are derived from plates taken at Cambridge by Mr A. R. Hinks and the writer, and measured and discussed by the latter in the course of his work as a research assistant of the Carnegie Institution. A full description of the methods of observation and reduction is given on pp. 775–800 of the *Monthly Notices* for June 1905.

Table I. gives the relative parallax of these stars with respect to comparison stars averaging about the 9th magnitude. The last column but one gives the number of comparison stars for each series, and the preceding column the number of plates in the series. The same comparison stars were used for Nos. 2 and 3, which appear on the same plates, and similarly for Nos. 7 and 8. The two bright stars β and η Cassiopeiæ were photographed with a colour-screen, which reduced their photographic brightness by about $5\frac{1}{2}$ magnitudes.

TABLE I.

Ref. No.	Star.	R.A. 1900.0 h. m.	Dec. 1900.0 ° ′	Mag.	P.M. ″	Parallax. ″	Plates.	Comp. Stars.	r_1. ″
1	β Cassiopeiæ	0 3·8	+58 26	2·4	0·55	+0·082±0·009	5	9	±0·014
2	Groombridge 34	0 12·6	+43 27	7·9	2·82	+0·250±0·012	6	9	±0·019
3	26 Andromedæ	0 13·5	+43 15	5·9	0·03	−0·026±0·041	6	9	±0·069
4	η Cassiopeiæ	0 42·9	+57 18	3·6	1·20	+0·188±0·021	7	8	±0·041
5	o Ceti	2 14·3	− 3 26	Var.	0·24	+0·136±0·035	7	9	±0·070
6	Lalande 25372	13 40·7	+15 27	8·5	2·32	+0·221±0·019	8	9	±0·032
7	Berlin B 5072	14 21·1	+24 6	9·0	1·42	+0·067±0·040	7	7	±0·073
8	Berlin B 5073	14 21·1	+24 6	9·1	1·42	+0·000±0·029	7	7	±0·052

The last column gives the probable error of a co-ordinate of each star, resulting from one plate, as derived from the least-square solution for the parallax. If we divide the stars into three classes according to their effective photographic brightness, we have three stars with faint images, Nos. 5, 7, and 8, four of moderate brightness, Nos. 1, 2, 4, and 6, and one star, No. 5, whose images are somewhat large and diffuse. The average values of the probable error of one plate for these three groups are $\pm 0''\cdot065$ for the faint stars, $\pm 0''\cdot027$ for those of medium brightness, and $\pm 0''\cdot069$ for the bright star.

This emphasises the importance of proper exposure when we wish to secure highly accurate plates. It would have been well if the exposures for the three faint stars, which were made of the usual length (five minutes), had been lengthened.

Stars brighter than the 6th magnitude were, as a rule, excluded from our working list, unless observed with a colour-screen. The large probable error for No. 3 (which was only measured because it happened to be on the plates of No. 2) justifies this course, while the two good results obtained with the colour-screen show that it affords a satisfactory way of avoiding the over-exposure difficulty.

Several of these stars have already been observed for parallax. The results, so far as known to the writer, are as follows:—

β Cassiopeiæ.

$\pi = +0''.15 \pm 0''.02$	Pritchard, photography.
$\pi = +0.14 \pm 0.03$	Kostinsky, absolute declinations.
$\pi = +0.10 \pm 0.03$	Flint, meridian transits.

Groombridge 34.

$\pi = +0.29 \pm 0.025$	Auwers, diff. of R.A., micrometer.
$\pi = +0.31 \pm 0.034$	Flint, transits.

η Cassiopeiæ.

$\pi = +0.10 \pm 0.05$	from distances } O. Struve,
$\pi = +0.37 \pm 0.10$	,, pos. angles } filar micrometer.
$\pi = +0.20 \pm 0.06$	from distances } Schweizer,
$\pi = +0.14 \pm 0.08$	,, pos. angles } filar micrometer.
$\pi = +0.44 \pm 0.04$	Davis, from Rutherfurd photographs.
$\pi = +0.34 \pm 0.04$	Flint, transits.
$\pi = +0.18 \pm 0.010$	Peters, heliometer.

Lalande 25372.

$\pi = +0.43 \pm 0.065$	Flint, transits.
$\pi = +0.17 \pm 0.043$	Elkin, heliometer.

Flint's results have received large corrections for systematic personal error, and the Rutherfurd photographs of η Cassiopeiæ, being taken at widely different hour angles, are affected to a considerable but unknown degree by atmospheric dispersion. If we reject the last, give Flint's values half weight, and the heliometer results double weight, we obtain mean values for the parallax of the four stars, from which the results of the present paper differ by $0''.05$, $0''.05$, $0''.00$ and $0''.00$ respectively.

If we assume that our results are responsible for two-thirds of the discrepancies, their average probable error would be $\pm 0''.020$, including the effects of any systematic error. It would therefore appear that the latter must be very small.

Examination of the residuals for the comparison stars shows no conspicuous evidence of parallax or proper motion except for B.D. $+43°$ 55 mag. 9.2 which appears on the plates of No. 2, and seems to have a proper motion of about $+0''.3$ in α. By Kapteyn's formula, the parallax of this star should be about

0″·029, while the average parallax of stars of the ninth magnitude is 0″·006.

We may therefore assume that the mean parallax of our comparison stars is 0″·009 for No. 2, and 0″·006 for the rest of our series. Adding this to the relative parallaxes of Table I., we obtain from the resulting absolute parallaxes the following values of the absolute magnitudes of the stars (*i.e.* their magnitudes if at such a distance that their parallax was 0″·10) and of their light in terms of the Sun's, and their velocities at right angles to the line of sight.

Groombridge 34 and η Cassiopeiæ are double, and data are given for both components, and for Mira at maximum (mag. 3·5) and minimum (9·5).

TABLE II.

No.	Star.		Absolute Mag.	Light.	Cross-velocity. Ast. units per year.	Cross-velocity. Kilometres per sec.
1	β Cassiopeiæ		2·1	23·	6·2	29
2	Groombridge 34	A	10·0	0·016	10·9	52
		B	12·6	0·0015		
4	η Cassiopeiæ	A	5·1	1·5	6·2	29
		B	9·1	0·04		
5	*o* Ceti	Max.	4·3	3·0	1·7	8
		Min.	10·3	0·011		
6	Lalande 25372		10·3	0·011	10·2	49
7	Berlin B 5072		(7·0)	(0·25)	(35)	(170)
8	Berlin B 5073		(7·1)	(0·23)		

Nos. 7 and 8, which are 45″ apart, have a common proper motion,* and are no doubt physically connected. The mean of the observed parallaxes, +0″·033 ± 0″·025, has therefore been taken as the true value for both stars, but it is clear that little reliance can be placed upon the numbers calculated from it. It is, however, probable that these stars are fainter than the Sun, and are moving across the line of sight faster than any of the others in the table.

The negative result for 26 Andromedæ is less than its probable error, and indicates that the parallax of this star is insensible. It was measured because the Bonn A. G. catalogue gives its proper motion in R.A. as $+0^{s}$·016, which is ten times the true value. If its actual cross-velocity is equal to the mean of that of the other stars (excluding Nos. 7 and 8), its parallax would be only 0″·004. It is double (OΣ 5), and its 10th magnitude companion is relatively fixed in 240°, 6″·1—which should be the case if its parallax is so small.

η Cassiopeiæ is a well-known binary. From Lewis's orbit †

* Bellamy, *M. N.*, Dec. 1899, p. 126.
† *Mem. R.A.S.*, vol. lvi. p. 16.

we have $a=8''\cdot51$ P=233 years, which with our parallax gives the mean distance of the components as 44 astronomical units. The actual distance varies from 58 to 30, and the combined mass is 1·6 times that of the Sun. According to Lewis, the bright star is twice as massive as the fainter one, so that it very nearly equals the Sun in mass as well as in light.

Groombridge 34 has a physical companion, which was measured by Auwers * in 1865, and is shown on some of the plates of the present series, as is also a fainter companion nearer the principal star.

The writer's measures, made this month with the 23-inch equatorial of the Halsted Observatory at Princeton, show that this is only an optical companion. They give, for the co-ordinates of the companions, relative to the principal star,

		B $10^{m}\cdot5$		C $11^{m}\cdot5$	
		x	y	x	y
Auwers	1866·23	+31''·2	+23''·4		
Plate 391	1904·98	+32·3	+21·6	+32''·0	−13''·3
Halsted Obs.	1906·78	+32·2	+21·5	+26·6	−14·2
	Proper motion of A in interval			+ 5·1	+ 0·7

This companion affords an unusually good opportunity for the micrometric determination of the parallax of the other two stars.

The actual separation of A B is at least 150 astronomical units —four times that of η Cassiopeiæ—so that we may expect the period of the system to be some thousands of years.

The results for Mira are also of interest. If the other long-period variables resemble it, and their maximum rather than their minimum light is comparable with the Sun's, the brighter ones must have easily measurable parallaxes, and it would pay to observe them.

Campbell and Stebbins † find that the radial velocity of Mira is constant, and equal to +63 km. per sec. As its cross-velocity is only 8 km., it is moving almost directly away from us—in a direction making an angle of only 7° with the line of sight.

If the present value of the parallax is correct, it follows that Mira was nearest the Sun about 110,000 years ago. It was then in Ursa Major, and had a parallax of $1''\cdot1$ and a proper motion of 15'' per annum. If its intrinsic brightness varied between the same limits as at present, it was of the 5th magnitude at minimum, and at maximum was as bright as Sirius.

Hearty thanks are due to Professor Lovett of Princeton for enabling the writer to continue the work here.

* *Math. Abth. Berlin Akad. der Wissenschaften*, 1867, p. 23.
† *Astrophysical Journal*, vol. 18, p. 341.

Princeton University Observatory:
1906 *October* 20.

Hansteen's Eclipse at Stiklastad, 1030 *August* 31.
By P. H. Cowell.

The record states that the eclipse occurred during the battle at Stiklastad at which Olaf the Fat was killed, and the date assigned to the battle is 1030 July 29. There are two reasons for supposing this date to be in error: the narrative mentions a dark night following the battle, whereas on July 29 the sun never sinks as much as 9° below the horizon of Stiklastad; also, Olaf was canonised, and July 29 became his festival and in time the supposed day of his death. Now August 31 was already at that time assigned to another saint. The foregoing arguments are Hansteen's (*Ast. Nach. Ergänzungsheft*, p. 49). Dr Dreyer (*The Observatory*, 1895 October, p. 363), quoting Prof. Konrad Maurer, decides against the later date for the battle. His arguments, as far as they are based on the day of the week, do not appear to me conclusive, as the chronicler may easily have counted backwards. But in any case we have a description of a total eclipse, that it was beyond the power of the chronicler to invent, and the eclipse is stated to have occurred at Stiklastad.

The eclipse has therefore been worked up. Considering its comparatively recent epoch, it might have turned out not to discriminate between the present tables and my formulæ. The very contrary is the case. My formulæ leave 3″ of the northern end of the Sun's diameter uncovered (indicating the possibility of small errors that I am quite prepared to admit). Hansen's tables and the present tables, which are practically the same for the epoch 1030, shift the Moon 35″ further south relatively to the Sun. The low altitude of the Sun makes this correspond to about 100 miles on the Earth's surface.

Outline of Calculations.

$$T = -7{\cdot}69303 = \quad 1030 \text{ Aug. } 31 + 28^{\circ}{\cdot}53 \text{ G.M.T.}$$

$g =$	286°	12′	41″·8	$L' =$	165°	0′	9″·8
$\omega =$	88	35	37·2	$\pi' =$	266	18	7·1
$-\Omega =$	207	10	12·3				

Inequalities of Moon's Longitude :—

A. Solar terms over 20″	$-$16	752″·7
B. „ 1·35	$-$	69·8
C. „ 0·15	$-$	5·0
Figure of Earth terms	$+$	4·9

Moon's Latitude and Sine Parallax :—

A. Solar terms over 10″	$+$3	089″·5	$+$3	500″·9
B. „ 0·55	$+$	27·0	$+$	0·1
C. „ 0·05	$-$	1·0	$-$	0·1
Figure of Earth terms	$-$	3·9		